



# ENCYCLOPEDIA OF TOXICOLOGY

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## Biological Exposure Index

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Human biological exposure indices are guidance levels of determinants for assessing worker dose from occupational exposures. They differ from other occupational exposure limits (OELs) for chemicals, which typically are measured in air, in that their determinants are measured in biological materials from the workers. BEIs consider the dose that has entered a worker's body by all routes. Thus, these measurements can provide more complete estimates of exposure, especially for chemicals that may be absorbed by routes other than inhalation and when inhalation rates are altered because, for example, of increased work rates.

### Defining Biological Exposure Indices

Most BEIs are defined as concentrations of determinants or biomarkers anticipated in biological specimens collected from healthy workers whose exposure to certain chemicals by all routes is equivalent to that of workers with inhalation only exposure at the OEL. Others measure reversible effects on the body, and still others are those that are below the concentrations associated with health effects. However, other definitions are common. For example, the German biological tolerance values (BAT) can be defined as rates of excretion of the chemical or its metabolites, or the maximum possible deviation from the norm of biological parameters induced by these substances in exposed humans. BEIs for some chemicals use other criteria, such as direct comparison with a measurable toxic effect, like carboxyhemoglobin in blood for carbon monoxide.

The most commonly used Biological Exposure Indices are known by the abbreviation, BEI<sup>®</sup>, which is a trademark of the American Conference of Governmental Industrial Hygienists (ACGIH<sup>®</sup>). Like most, ACGIH defines BEIs as guidance values for assessing human biological monitoring results. ACGIH indicates that most of its BEIs are bioequivalent to its airborne OELs, the threshold limit values (TLVs<sup>®</sup>): a “BEI generally indicates a concentration below which nearly all workers should not experience adverse health effects.” It also asserts that BEIs should not be used as measures of adverse health effects or for diagnosing occupational illness. In addition to the ACGIH BEIs and German BATs, other sources of BEGs include the Finnish Institute of Occupational Health, United Kingdom Health and Safety Executive, Italian Society of Reference Values, and the Japan Society for Occupational Health.

The determinant for a biological exposure index can be the chemical itself, one or more metabolites, or a characteristic biochemical change induced by the chemical. The specimen used for biological monitoring usually is urine, blood, or exhaled air. For example, the BEI for trichloroethylene includes four determinants:

a metabolite, trichloroacetic acid, in urine;

another metabolite, trichloroethanol, in blood;

the parent compound, trichloroethylene, in blood; and trichloroethylene in end-exhaled breath.

The latter two determinants are recommended as confirmatory tests to document exposure to trichloroethylene, since other chemicals also can be metabolized to trichloroacetic acid and trichloroethanol.

### **Basis for Biological Exposure Indices**

While most BEIs are based on overall exposures equivalent to inhalation exposures at an OEL, several provide the basis for the corresponding airborne OEL. For example, airborne OELs for carbon monoxide, acetylcholinesterase inhibitors, certain solvents like hexane, and most heavy metals represent inhalation exposures that are expected to cause measurable biological concentrations or changes that available data indicated should be safe for most workers. For substances with low potential for inhalation exposure that are readily absorbed through the skin, there is likely to be little correlation between airborne concentrations and measurement of biological determinants. BEIs for these substances are based on the relationships between health effects and the biological concentrations of the determinants.

While most BEIs are quantitative, data sometimes support only a screening-type guideline that is nonquantitative or semiquantitative. Such guidelines typically are used for substances on which there are good qualitative data on human exposure and the biological determinant concentration, but poor quantitative data relating exposure to the determinant. They most commonly are used for substances that cause chronic, systemic health effects when absorbed through the skin. Nonquantitative determinants are useful especially for substances, like 4,4'-methylene bis(2-chloroaniline) (MBOCA), that meet these criteria and for which there is a long lag time from exposure to health outcome and low or no background level of the determinant in the unexposed population. While there are several good methods to measure either MBOCA or its metabolites in urine, none of these measurements relates well enough to exposure or risk of health effects to determine a quantitative biological exposure index. So, for example, the ACGIH BEI for MBOCA is a nonquantitative guideline for total MBOCA in urine.

### **Applying Biological Exposure Indices**

In addition to providing comprehensive estimates of recent exposures, in many cases biological monitoring can allow health professionals to do one or more of the following:

- measure body burden of a chemical;
- supplement air monitoring to document exposures;
- detect small exposures;
- distinguish nonoccupational exposures;
- identify unknown or undiscovered exposures, especially from noninhalation sources such as dermal absorption or ingestion;
- examine effectiveness of engineering controls, work practices, and personal protective equipment;
- follow trends of exposure over time;
- reconstruct past exposures; and
- enhance individual or group risk assessments.

As is the case for all types of OELs, credible BEIs are explained and supported by documents that critically review the scientific criteria on which they are based and often provide practical information for their application. These documentations generally describe the following types of pertinent information:

scientific rationale;  
sampling and analytical methods;  
quality control measures;  
issues related to specimen collection and storage;  
potential for confounding exposures;  
typical background concentrations of the determinant;  
quality of the relevant database;  
other limitations; and  
research needs.

Like all occupational exposure values, BEIs should be used by knowledgeable health professionals who understand their bases and how they are intended to be applied.

**See also:**

[American Conference of Governmental Industrial Hygienists; Occupational Toxicology; Occupational Exposure Limits.](#)

**Further Reading**

[1] ACGIH. Documentations of the Biological Exposure Indices for Chemical Substances, 7th edn. 2001. Cincinnati: American Conference of Governmental Industrial Hygienists.

[2] ACGIH. TLVs and BEIs. 2004. Cincinnati: American Conference of Governmental Industrial Hygienists.

[3] Deutsche Forschungsgemeinschaft. Biological Exposure Values for Occupational Toxicants and Carcinogens vol. 3, 1998. Weinheim, Germany: Wiley-VCH.

[4] Deutsche Forschungsgemeinschaft. Biological Tolerance Values. List of MAK and BAT Values. 2004. 189–197. Weinheim, Germany: Wiley-VCH.

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